STUDIES ON CHEMICAL CHANGES DURING THE LIFE CYCLE OF THE TENT CATERPILLAR (MALACOSOMA AMERICANA FAB.)

V. WEIGHT AND DATA[1]

BY WILLEM RUDOLFS[2]

In former publications (1) curves and discussions have been presented on the results obtained in a study of the chemical changes taking place during the life cycle of the tent caterpillar. Measurements and weight of the growing larvæ, the original data, together with a brief general summary are the purpose of this paper.

MATERIAL

A collection of about one thousand egg masses of the tent caterpillar were kept in an insectary from which lots of from 50 to 75 egg masses were used for analyses. Another lot was kept in the laboratory and subjected for about 2½ days to a constant temperature of 80° F. and constant atmospheric moisture content of 73.4 per cent. After the caterpillars were formed in the egg-shells they were removed by hand and some analyses made. The caterpillars upon hatching were analyzed in lots of from 50 to 1,000, depending upon the size. Pupæ and adults were analyzed in lots of about 50 individuals.

RESULTS

After the egg-masses had been in the insectary for about two months the weight of the egg-masses was apparently determined mainly by the moisture content of the larvæ. The relation is shown in table 1, where the results obtained from individual egg-masses are given.

[1] Journal Series paper of the N. J. Agricultural Experiment Station, New Brunswick, N. J. Dept. of Entomology.

[2] Chief, Dept. Sewage Research.

TABLE 1

WEIGHT OF EGG-MASSES AND LARVÆ

	July	Aug.	Sept.	Nov.	Jan.
Number of eggs	330	360	355	320	370
Total weight one mass (gr.)	.0990	.1040	.1000	.0905	.1015
Weight of larvae (gr.)	.0545	.0565	.0530	.0434	.0555
Percentage weight of larvæ	55.1	54.0	53.0	51.9	48.0
Percentage moisture larvæ	61.9	58.2	56.2	52.2	49.1

Atmospheric conditions affected the wet weight of the egg-masses also to some extent. The following most widely varying results between egg-masses taken from the insectary and those subjected to a constant conditioned air stream show this:

Moisture content of egg-masses from:

Insectary	Air stream
per cent.	*per cent.*
42.48	44.80
43.79	40.97
44.86	39.19

The results obtained on chemical analyses of the larvæ taken from the shells are given in table 2, while the results obtained

TABLE 2

ANALYSES OF LARVAE TAKEN FROM EGGS

Date	Moisture	Soluble ash	Total nitrogen	Ether soluble
July	61.9	5.03	9.42	0.46
Aug.	58.2	4.40	....	....
Sept.	56.2	4.43	10.00	1.06
Oct.	54.1	4.40	10.45	0.95
Nov.	52.2	4.20	10.80	0.90
Dec.	50.8	3.80	11.55	0.90
Jan.	49.1	3.64	12.07	0.75
Feb.	44.4	....	14.20	0.35

on the average weight and average length of the larvæ, and the chemical analyses of larvæ, pupæ and adults are shown in table 3. During the year monthly analyses were made on

TABLE 3

LENGTH, WEIGHT AND CHEMICAL CONSTITUENTS OF LARVAE, PUPAE AND ADULTS

Number	Date	Average weight	Average length	Moisture	Total ash	Total nitrogen	Ether soluble (fat)	Sulfates	Carbonates	Glycogen	Soluble ash	
		mgr.	*mm.*	*per cent.*	*per cent.*	*per cent.*	*per cent.*	*per cent.*	*per cent.*	*per cent.*	*per cent.*	
9	4/1	0.3	2–2.5	39.4	6.67	15.10	0.66	0.24	5.22	2.79	5.46	Newly hatched
10	4/6	6.0	4–5	68.5	3.74	......	1.74	0.26	5.90	2.92	3.52	Growing larvae
11	5/6	18.5	12–14	83.8	4.93	10.50	5.85	0.24	6.40	2.65	4.63	" "
12	5/9	52.0	18	84.3	6.67	9.90	7.88	0.27	7.60	2.03	7.90	" "
13	5/11	68.8	20	85.1	9.25	10.30	8.56	0.11	6.10	1.82	6.20	" "
14	5/15	197.3	28	84.0	7.54	9.00	9.42	0.12	5.90	1.30	6.00	" "
15	5/17	237.6	32	82.9	6.39	9.00	10.04	0.22	6.00	0.78	6.26	" "
16	5/18	313.5	34	85.4	7.73	9.20	11.04	0.39	7.00	0.48	7.37	" "
17	5/21	684.8	40–42	82.1	7.17	8.45	15.06	0.27	6.80	0.23	7.04	" "
18	5/27	642.0	42–46	79.3	8.13	10.55	18.71	0.02	7.00	0.15	7.03	Full grown, become flabby
19	5/29	463.0		72.1	3.18	9.36	24.05	0.02	2.50	0.74	2.54	Prepupal stage
20	5/31	357.0		71.0	3.81	8.26	28.82	0.01	3.75	0.45	3.76	Just pupated, color lemon
21	6/8	250.0		64.1	4.33	9.89	26.01	0.01	4.30	0.08	4.33	Ready to hatch, some in act
22	6/12	185.3		59.9	2.87	9.03	24.70	0.008	2.60	......	2.62	Adult (26 males, 22 females)

NOTE.—Chemical analyses all on basis of dry weights of insects.

batches of egg-masses. The analytical results are given in table 4.

TABLE 4

ANALYSES OF EGG-MASSES

Date	Moisture	Total ash	Soluble ash	Fats	Total nitrogen	Sulfates	Carbonates
	per cent.	*per cent.*	*per cent.*	*per cent.*	*per cent.*	*per cent.*	*per cent.*
June 22	48.5	1.32	0.41	4.45	11.49	0.16	0.25
July 18	45.5	1.93	1.85	1.71	12.82	0.30	1.45
Aug. 11	40.8	2.30	2.11	1.48	12.82	0.36	1.75
Sept. 13	42.0	2.35	2.12	1.40	13.02	0.35	1.80
Oct. 30	46.2	2.49	2.14	1.32	13.32	0.35	1.82
Nov. 17	42.5	4.07	2.76	1.21	14.00	0.42	2.34
Dec. 15	43.0	3.75	2.80	1.12	13.10	0.42	2.20
Jan. 12	43.8	3.32	2.58	1.06	13.07	0.39	2.19
Feb. 18	44.8	3.90	2.90	0.56	14.29	0.49	2.41

One more or less complete analysis of the cover and egg-shell as compared with the egg-mass was made. The results are partially shown in table 5. The larvæ taken from these egg cases

TABLE 5

ANALYSES OF EGG-MASSES, COVER AND EGG-SHELLS

	Egg-mass	Cover	Egg-shells*
Moisture, per cent.	42.50	8.30	15.70
Total ash, per cent.	4.04	2.46	0.74
Insoluble ash, per cent.	1.30	0.12	trace
Sulfates, per cent.	0.46	trace	trace
Carbonates, per cent.	trace	0.0	trace
Chlorides, p.p.m.	0.45	0.1	trace
Amino-nitrogen, per cent.		0.835	
Ammonia nitrogen, p.p.m.	13.4	35.4	
Albuminoid nitrogen, p.p.m.	669	1062	
Ether soluble (fat), per cent.	1.20	0.0	
Glycogen, per cent.	2.31	0.48	

* Traces of cover adhering to egg-shells.

contained 2.87 per cent. of glycogen. The egg-masses gave positive tests for urea, tryptophane, xanthoproteic reaction, reduced sulfur reaction (cystine, cysteine), carbohydrates, sugars and phosphorus. They showed a negative test with Millon' reaction, Ehrlich's diazo reaction (histidine, tyrosine) and cholesterol. The covers were positive for urea, tryptophane, reduced sulfur, carbohydrates and phosphorus. All other tests showed negative.

DISCUSSION

The average weight of the larvæ increased rapidly during this part of the life cycle of the insects. With the gradual increase in weight the moisture content increased rapidly and remained fairly constant after the first two instars until they were full grown. The weight and moisture content decreased again during transformation. However, the decrease in weight was greater than the reduction in moisture content. The decrease in wet weight of the full grown larvæ to the adult amounted to 81 per cent., whereas the decrease in moisture content amounted to 50.7 per cent.

The percentage ether soluble material (fats) increased gradually during the first two instars, increased rapidly during the next three instars and increased at an accelerated rate during

TABLE 6

DRY WEIGHT, FATS AND NITROGEN CONTENTS PER INSECT

No.	Dry weight	Fats	Total nitrogen
	mgr.	*mgr.*	*mgr.*
9	.18	.0012	.027
10	1.92	.0143	......
11	3.0	.175	.32
12	9.4	.740	.93
13	10.2	.875	1.05
14	31.5	2.97	2.83
15	40.3	4.03	3.62
16	47.5	5.17	4.37
17	122.0	18.40	11.05
18	133.0	24.85	14.05
19	129.0	31.00	12.10
20	103.0	29.65	8.50
21	90.0	23.40	8.90
22	74.3	18.35	6.70

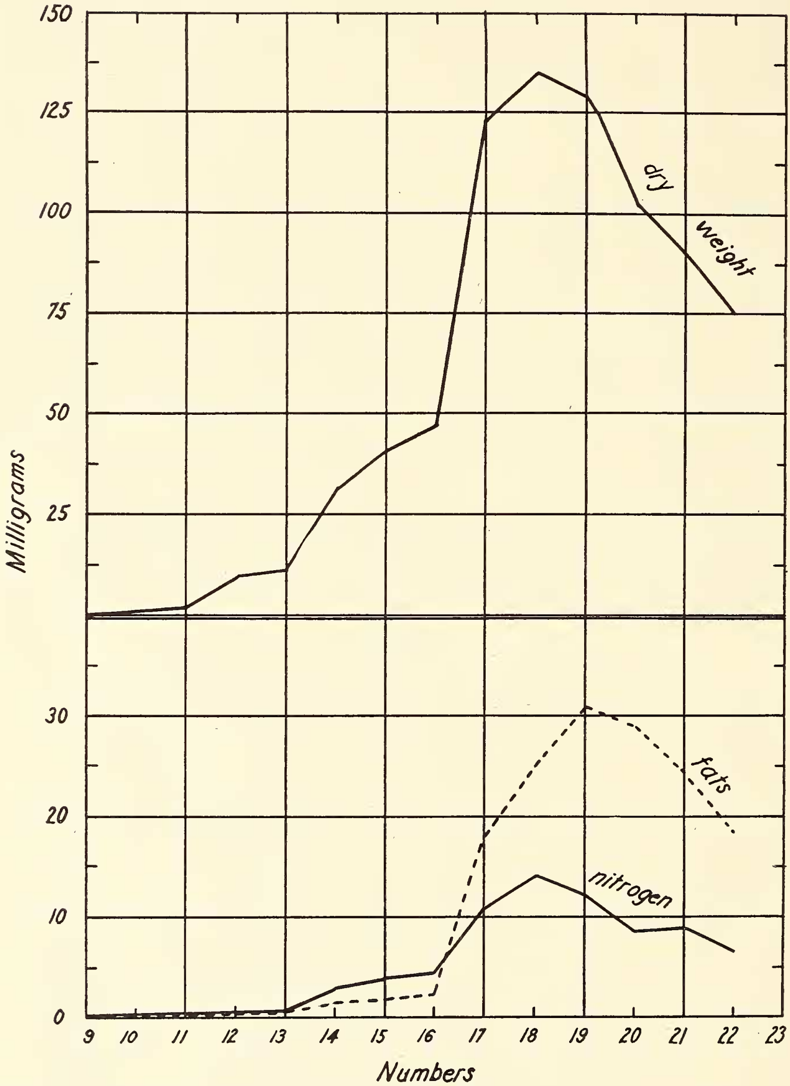

FIG. 1. Relation between dry weight per insect and weight of fats and nitrogen of larvæ, pupæ and adults.

the first part of metamorphosis, while the percentage decreased during the second part. However, the actual amount of ether soluble material per insect decreased somewhat during the first part of metamorphosis (table 6). The relation between the dry weight of the insects and the weight of fats and nitrogen is shown in figure 1. While the insects were losing some moisture just before pupation, fat production continued somewhat, but as soon as the transformation processes began the fat content decreased with the result that 41 per cent. of the fats were consumed between the prepupal stage and the full grown adult.

Total nitrogen per dry insect increased in the rapidly growing larvæ at a slightly faster rate than the fats. A considerable actual loss of nitrogen took place during pupation processes. While the fat content decreased 24 per cent. between the prepupal and ready to hatch stages, the nitrogen loss amounted to 38 per cent. It is also interesting to note that the total amounts of fats still increased from the full grown to prepupal stage, while the nitrogen decreased, indicating that the first transformation processes were made at the expense of nitrogen present.

Upon hatching the soluble ash content was higher than a few days later, probably due to waste products stored when the insects remained in the egg-cases. After the initial drop there was a persistent increase of soluble ash in the growing larvæ.

The percentage of glycogen in the growing larvæ decreased but the actual amount increased rapidly. There was apparently no storage of glycogen as was the case with fats.

The monthly analyses of egg-masses (table 4) showed some fluctuations in moisture content with an increase in total and soluble ash. The fats decreased materially and some increase in total nitrogen. It is of interest that the larvæ taken from the egg-shells (table 2) increased gradually in nitrogen content. The carbonates and sulfates, considered to be a part of the end products of the life processes, increased in the egg-masses. It may be seen that the percentage of soluble ash of the larvæ encased in the egg-shells decreased somewhat. The end products were apparently deposited in the egg-shells.

The initial purpose of the study was an inquiry in the general changes and fluctuations of the chemical constituents of an insect to obtain, if possible, an insight into the accumulation and decomposition of materials utilized in the life processes. The need for correlation of biochemical changes taking place in the life cycle of insects with environmental conditions, food plants, composition of soils, etc., is apparent. Such studies require long and painstaking work without much hope for immediate practical results. Every small contribution will help in the understanding of the vast problems involved and may bear fruit in the future. The studies reported are only a small part of the envisioned work and the results are far too scanty to allow general conclusions to be drawn. Correlation between the gross biochemical changes and the types and amounts of enzymes present during the different stages; types, fluctuations and quantities of intermediate products (sugars, amino-acids, etc.); occurrence and quantities of other inorganic constituents (phosphorus, potash, silicon, etc.) all would be necessary to complete the picture before real progress could be made with comparisons of food plants, geochemical factors and climatic conditions.

REFERENCES

(1) Rudolfs, W. Jour. N. Y. Entom., v. 34, p. 249; v. 34, p. 320; v. 35, p. 220; v. 37, p. 17.